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EVALUATION OF SHALLOW AQUIFERS IN THE HELENA VALLEY, LEWIS AND CLARK COUNTY, MONTANA

By Joe A. Moreland and Robert B. Leonard

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METRIC CONVERSION TABLE

The following factors can be used to convert inch-pound units in this report to the International System (SI) of metric units.

Mutiply inch-pound unit	By	To obtain metric unit
acre	4047	square meter
cubic foot per day (ft^3/d)	0.02832	cubic meter per day
foot	0.3048	meter
foot per mile (ft/mi)	0.1894	meter per kilometer
foot squared per day (ft^2/d)	0.09290	meter squared per day
gallon	3.785	liter
gallon per day (gal/d)	3.785	liter per day
gallon per minute (gal/min)	0.06309	liter per second
inch	0.02540	meter
mho	1.0	siemens
mile	1.609	kilometer
square mile (mi^2)	2.590	square kilometer

temperature, degrees Celsius (°C) = 0.556 (°F-32)

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ABSTRACT

Shallow aquifers underlying the Helena Valley in west-central Montana were evaluated in response to a general concern about the potential for contamination from sewage effluent and other wastes. Water-level data collected from 52 test wells augered in the valley were used to construct a depth-to-water map that shows large areas underlain by shallow ground water (less than 5 feet below land surface). Hydrographs for selected wells show that water-level fluctuations range from about 15 feet near the margins of the valley to about 2 feet in lower lying areas. Although water levels in wells in most areas of the valley are highest during July or August, some water levels are highest during the spring months.

Aquifer tests in five wells indicate that transmissivity of the unconsolidated sand and gravel aquifers is about 1×10^4 feet squared per day. The tests also indicate that pumping can induce or increase the rate of drainage from the saturated material overlying the shallow aquifers.

Water samples collected from the test wells and from 11 domestic wells show that water quality is generally acceptable for domestic use, although nitrate concentrations exceeded 10 milligrams per liter in two of the test wells. On-site determinations of nitrate concentration and specific conductance of samples from the test wells and from 98 domestic wells show significant variations. The largest nitrate concentration for water from a domestic well was 7.6 milligrams per liter. The largest specific conductance determined was 1,620 micromhos per centimeter at 25° Celsius in a test well. Large values for both nitrate and specific conductance are related to the impacts of man's activities in many parts of the valley.

INTRODUCTION

The Helena Valley is a rapidly developing area of about 100 mi^2 north and east of Helena, Mont. (fig. 1). Most of the nearly 5,000 valley residents obtain water for domestic use from individual wells. A few subdivisions are served by community wells and central distribution systems. Most of the residents depend on septic tanks and soil-absorption systems (drain fields) for sewage disposal. A few subdivisions have central collection systems for disposal of domestic wastes in sewage lagoons. The shift from rural to suburban land use has been accompanied by increased withdrawal of ground water and discharge of effluent waste by domestic water systems, normally in close proximity.

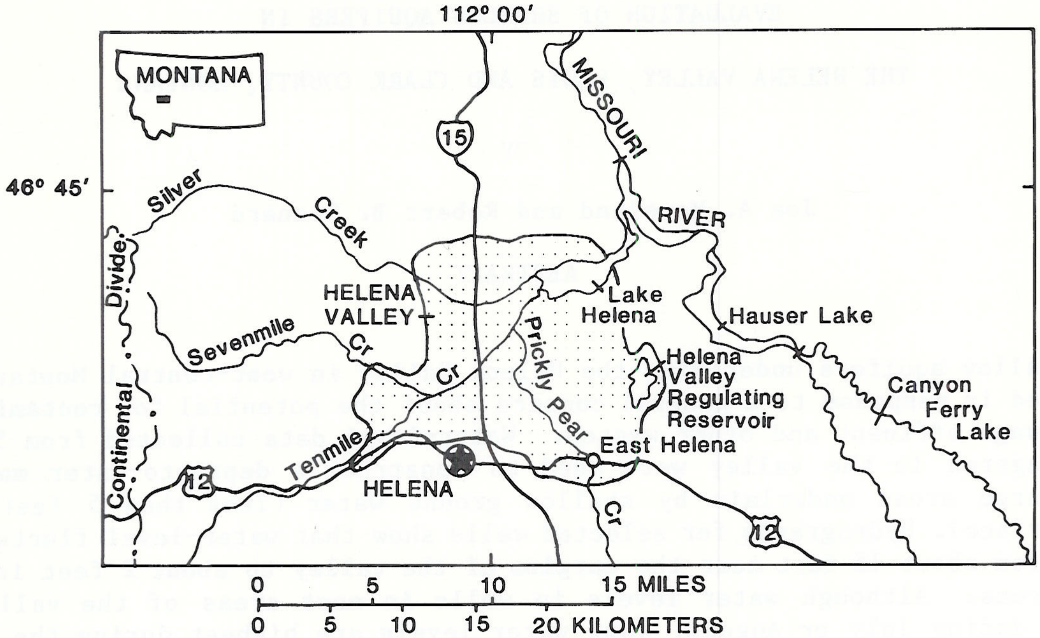

Figure 1.--Location of Helena Valley.

Sewage effluent may contain many chemical and biological contaminants that, if disposed in the ground water, could render it unfit for human consumption. Chemical pollutants are as numerous as the household products which find their way to the kitchen sink. Detergents, solvents, pesticides, drain cleaners, petroleum products, food preservatives, and even unused medicine are commonly disposed down household drains. Some, such as nonbiodegradable detergents, can cause nuisance problems (in this instance, foaming), whereas others are toxic even in minute concentrations. Biological contaminants such as bacteria and virus could result in widespread outbreaks of contagious diseases including influenza, hepatitis, and cholera.

Residents of the valley and county officials are concerned that sewage effluent from soil-absorption systems and lagoons, as well as industrial (smelter), municipal, and agricultural waste, may percolate to the shallow aquifers. Although most domestic wells in the valley are drilled through at least one layer of fine-grained material to avoid the potentially contaminated water in the shallowest aquifers, sewage effluent eventually may percolate downward to the aquifers used for domestic supply. Chemical or biological contamination of the ground water could deprive the residents of an economical potable water supply. The rapid increase in population density might accelerate the rate and severity, as well as the economic effects, of contamination. In response to the general concern, the Lewis and Clark County Commissioners requested an investigation of the potential for contamination of the shallow aquifers in the area. This report summarizes the findings of that investigation.

Purpose and scope

The purpose of the study was: (1) To evaluate the geologic and hydrologic factors that control the movement of water and potential contaminants into and within the shallow aquifers, and (2) to describe current ground-water quality and historic changes. The following specific objectives are useful for evaluating the potential for degradation of domestic water supplies, caused by downward movement of effluent waste:

1. Determine the depth to ground water and the magnitude of seasonal variations in the water table.
   (Physical, biological, and chemical changes occur in the soil zones above the water table. Oxygen in the unsaturated zone initiates chemical changes (oxidation) and sustains biological activity (decomposition) that can alter or neutralize many of the potential contaminants.)

2. Determine the lateral and vertical extent of layered fine-grained sediment that might prevent or retard downward percolation of contaminated shallow water into the aquifers used for water supply.
   (Valley residents have placed much faith in stratification of ground water. The alluvial sediments that comprise the aquifers underlying the valley consist of alternating layers of gravel, sand, silt, and clay. This layering causes ground water to move preferentially in a horizontal direction through the coarse-grained material rather than vertically across the less permeable fine-grained layers. Thus, water entering the ground-water system at the top of the saturated zone (as sewage effluent) would tend to remain there unless vertical hydraulic-head differences existed to drive water downward. In areas where layers of silty clay or clay exist near the surface, the contaminants might be effectively perched above the underlying ground water. Even in areas underlain by fine-grained material, improperly constructed wells could provide an avenue for downward moving water between the casing and the well bore. Also, if fine-grained layers are absent or discontinuous, contaminants could move vertically under certain hydrologic conditions.)

3. Determine the transmissivity of the aquifers for estimating the rate of movement of water through the aquifer.
   (If the total pollutant load is small compared to the amount of water moving through the aquifers, simple dilution may afford protection. Therefore, a knowledge of the total underflow would be useful in assessing the potential for contamination. The transmissivity can be used with water-level gradients to determine the rate of ground-water flow.)

As part of the study, the U.S. Geological Survey augered 52 test holes at selected locations (see pl. 1) throughout the valley. The holes ranged in depth from 19.6 to 67.0 feet and were cased with unperforated steel pipe. Perforated sand points 30 inches long were installed at the bottom of each test hole. Water-level measurements and water samples were obtained periodically from these test wells from the fall of 1978 to the fall of 1979. A total of 165 samples from the test wells were analyzed for chemical constituents.

In addition, water samples were collected from 98 domestic wells in May and June 1979 to document current water-quality conditions in the aquifers being used for domestic supplies. Measurements of water temperature, specific conductance, and nitrate concentration were made at the well sites. To further document water quality, samples from 11 wells were analyzed for the most common major and minor constituents.

Gamma-ray geophysical logs were obtained from selected wells to determine the location of fine-grained sediments. Used in conjunction with drillers' logs, the geophysical logs provided an indication of vertical and areal extent of silt and clay deposits that could prevent or retard downward percolation of effluent.

The transmissivity and other properties of the aquifers were determined from aquifer tests conducted at five well sites. This information, together with water-level gradients, is useful in estimating the amount and direction of ground water moving through the system.

The water-quality analyses and water-level data are contained in a report by Moreland, Leonard, Reed, Clausen, and Wood (1979). Gamma-ray logs are on file in the U.S. Geological Survey office in Helena, Mont.

Numbering system for wells

In this report, sites are numbered according to geographic position within the rectangular grid system used by the U.S. Bureau of Land Management (fig. 2). The location number consists of as many as 14 characters. The first three characters specify the township and its position north (N) of the Montana Base Line. The next three characters specify the range and its position west (W) of the Montana Principal Meridian. The next two characters are the section number. The next three or four characters designate the quarter section (160-acre tract), quarter-quarter section (40-acre tract), quarter-quarter-quarter section (10-acre tract), and quarter-quarter-quarter-quarter section (2 1/2-acre tract) in which the well is located. The subdivisions of the section are designated A, B, C, and D in a counterclockwise direction, beginning in the northeast quadrant. The final two characters are sequence numbers that represent the order in which the wells are inventoried. For example, as shown on figure 2, well 11N03W21BAAA01 is the first well inventoried in the NE1/4 NE1/4 NE1/4 NW1/4 sec. 21, T. 11 N., R. 3 W.

Acknowledgments

This cooperative study was funded by the U.S. Geological Survey, the Lewis and Clark County Commissioners, and the Montana Bureau of Mines and Geology. Personnel of the City-County Health Department assisted in gaining access to drill the test holes, in collecting data, and in analyzing the information.

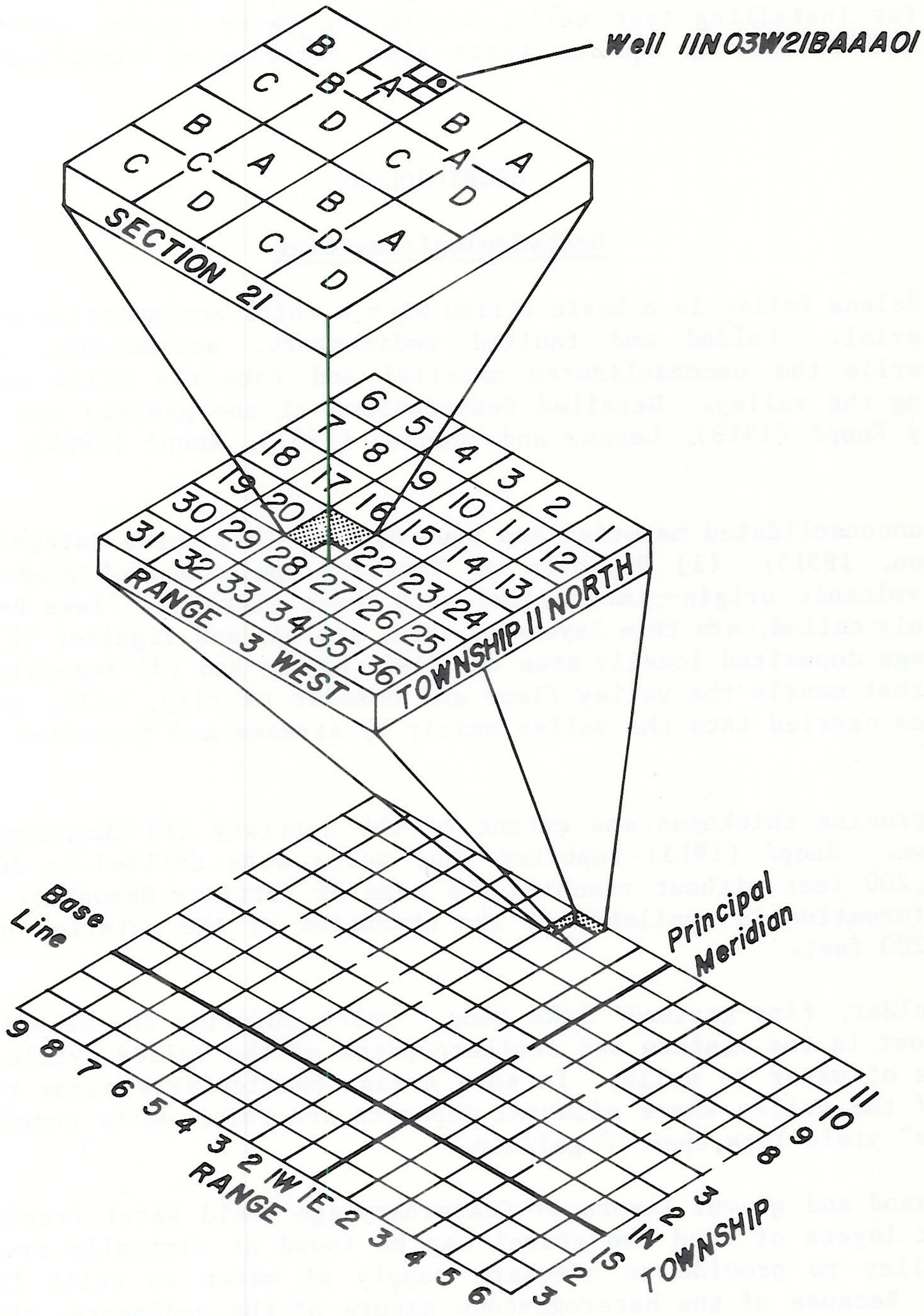

Figure 2.--System for numbering wells.

Many of the water samples analyzed as part of this investigation were collected by Charlotte Beckett, City-County Health Department. Her efforts contributed greatly to the successful completion of the study. Most of the chemical analyses reported in this study were made by the Montana Bureau of Mines and Geology, Analytical Division. Local landowners who granted access to their property for installing test wells, monitoring water levels, collecting water samples, and conducting aquifer tests also contributed significantly to the study.

GEOHYDROLOGY

Geohydrologic setting

The Helena Valley is a basin filled with a thick accumulation of unconsolidated material. Folded and faulted sedimentary, metamorphic, and igneous rocks underlie the unconsolidated material and form the hills and mountains surrounding the valley. Detailed descriptions of the geology can be found in reports by Knopf (1913), Lorenz and Swenson (1951), Knopf (1963), and Schmidt (1977).

The unconsolidated material has been divided into three categories (Lorenz and Swenson, 1951): (1) Deposits of Tertiary age composed predominantly of clays of volcanic origin--interbedded with these clays, or "lake beds" as they are commonly called, are thin layers of sand, gravel, and lignite; (2) gravels of Pliocene age deposited locally atop the "lake beds"; and (3) deposits of Quaternary age that mantle the valley floor and consist of clay, silt, sand, gravel, and cobbles carried into the valley mainly by streams and deposited as alluvial fans.

The precise thickness and extent of the Tertiary and Quaternary deposits are unknown. Knopf (1913) reported that wells were drilled to depths of as much as 1,200 feet without reaching the base of Tertiary deposits. Relatively little information is available on the character of the material below depths of about 200 feet.

The older, fine-grained "lake beds," which underlie the alluvial material and crop out in the eastern and southern parts of the valley, yield only small quantities of water to wells. In some areas, particularly along the northern margins of the valley where alluvial deposits are thin, wells completed in the "lake beds" yield less than 10 gal/min.

The sand and gravel layers of Quaternary age yield water freely to wells. Sufficient layers of sand and gravel can be found at virtually every location in the valley to provide an adequate supply of water to wells for domestic purposes. Because of the heterogeneous nature of the sediments, the layers of sand and gravel form a complex, but generally interconnected, system of aquifer zones that are considered as one multiple-aquifer system. Several large-capacity wells (pumping in excess of 500 gal/min) have been constructed.